AN OPTICAL OFFGAS SENSOR NETWORK INCORPORATING A HG CAVITY RINGDOWN SPECTROMETER AND NIR DIODE LASERS

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Abstract:

Objectives: An innovative combination of optical sensor technologies is being explored with the objective of developing intelligent control systems for advanced coal combustion systems. The foundation of the project involves coupling of classical IR absorption spectroscopy (using tunable NIR/IR lasers) together with UV cavity ringdown spectroscopy to provide real-time data on to monitor typical emission gases, (for example: CO_2, CO, NO, NO_2, N_2O, SO_2, and mercury). This combination of optical sensors has the potential for providing the significantly increased sensitivity, while maintaining the ability to work reliably in the hostile environment, required by advanced coal-powered combustion facilities.

The experimental technique that forms the core of this project is based on cavity ringdown spectroscopy (CRDS). CRDS is a sensitive absorption technique that was first developed by O'Keefe and Deacon in 1988. This technique injects a pulse of light into a stable optical cavity formed by two highly reflecting mirrors. The light reflects back and forth in the cavity giving extremely long effective pathlengths. Using mirrors with a reflectivity of 99.99% or better, it is possible to achieve an effective pathlengths exceeding 10 kilometers. The measured time constant for the exponential decay of light within the cavity is called the "ringdown time".

The dominant loss mechanism for an empty cavity is the reflectivity of the mirrors. If a sample species, which absorbs light at a particular wavelength, is placed within the cavity the ringdown time will decrease from that of the empty cavity (at that particular wavelength). This ringdown time is given by

$$\tau = \frac{l_c}{c[(1-R)+\alpha l_s]} \qquad (1)$$

where, l_c is the cavity length, R is the reflectivity of the mirrors, α is the absorption coefficient of the sample species of interest, and l_s is the pathlength through the sample. Once the empty cavity

losses have been determined, CRDS provides an absolute measure of the concentration of the absorbing sample within the cavity. This self-calibrating feature differentiates CRDS from other highly sensitive laser-based methods such as laser-induced fluorescence (LIF) or resonantly enhanced multiphoton ionization (REMPI).

The laser sources being used for the project are a 10 Hz Nd-YAG-pumped laser (linewidth of 0.03 nm) and a commercially-available tunable (1520 – 1570 nm) NIR diode laser. The laser pulses are spatially filtered and mode matched to two coupled cavities. The cavities, making up the absorption cells, are constructed with highly-reflective plano-concave mirrors. The initial gases to be measured include CO, SO_2 and mercury.

Accomplishments to date: At the time of writing, we have completed the design and are in the process of building and aligning the dual sampling cavity. In addition, a graduate student is modifying existing labview-based software to control both the Dye laser and diode laser systems as well as analysis the data. Equipment has been ordered to permit the upgrading the dye laser to allow it to lase at 253 nm has been ordered.

Future Work: Once the dye laser has been upgraded and we have identified the most appropriate IR/NIR wavelengths (to avoid potential interferences expected from other gases in the exhaust stream) we will proceed to undertake simultaneous experiments measuring $Hg/SO_2/CO$ concentrations using both the dye laser system and a NIR/IR sensor. This data will be analyzed with respect to its impact on intelligent control requirements. The potential to expand this network to include additional sensors and sensing techniques will also be investigated.

In summary, during phase I of this project the control and data analysis functions for multiple highly sensitive sensors are being interfaced, via a labview program, to provide an evaluation of the potential of such a network to assist in the development of intelligent control systems for advanced coal combustion systems.

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